CIRCULATION OF THE CŒLOMIC FLUID IN A NEMATODE.

FREDERIC H. KRECKER.

The nematodes are not known to have a special circulatory system and it has been rather generally considered that they do not possess a circulating medium.

In some nematodes of the genus *Camallanus* taken from the rectum of a sunfish (*Apomotis cyanellus*) I noticed a flowing movement of the cœlomic fluid. It was blood red and could therefore be easily distinguished. Waves of the fluid passed from the anterior to the posterior end and then in the reverse direction.

The reversal of the circulation calls to mind the condition in ascidians. In them it will be remembered, there is a clearly defined circulatory system and the reversal of blood flow is due to the heart forcing the blood first in one direction for twenty or thirty beats and then, after a pause, sending it in the opposite direction. The only similarity in these two instances lies in the fact that in both of them the circulating medium is impelled first in one direction and then in the other.

Before describing fully what occurs in these nematodes it might be best to point out briefly such of their structural features as have a bearing on the phenomena. The specimens at hand are all females from 20 to 25 mm. long. As commonly happens among nematodes the uterus extends practically the entire length of the cœlom. It is so distended with embryos that in optical section it appears to be in contact with the body wall. As a matter of fact there is just enough space between the two for a thin layer of cœlomic fluid.

The circulation of the fluid is brought about by peristaltic contraction of the uterus. The ability of these constrictions to force the fluid along is due to there being more of it than can be accommodated in the narrow peri-uterine space. A sharp constriction of the uterus forms a comparatively deep depression

which becomes filled with cœlomic fluid. This constriction moves as a wave lengthwise of the uterus and carries fluid along because the latter cannot easily escape.

The description of the entire process is as follows, beginning, for the sake of convenience, when the fluid leaves the posterior end. The peri-uterine space of this end is at this time filled with cœlomic fluid for approximately one-sixth of the worm's entire length. A peristaltic wave arises at the posterior end of the uterus and moves anteriorly. This is followed by another, then a third and sometimes a fourth. Each wave carries with it some of the fluid, the first taking the largest or primary wave of fluid, the third or the fourth, if there is a fourth, taking the least. The three waves all leave within seven seconds at slightly over two second intervals. After the last wave has left, only a thin film of fluid remains in the peri-uterine space. At about the time when the first of the peristaltic waves starts from the posterior end of the uterus, posterior to anterior waves of peri stalsis are to be seen at its anterior end, each of them pushing along a little fluid. It was rather difficult to watch both ends of the worm at the same time and so my observations on what were practically synchronous occurrences may be subject to slight error. There are usually three of these peristaltic waves at the anterior end and then, with the fourth, comes the primary wave of fluid from the posterior. This wave arrives at approximately the time when the third wave is leaving the posterior end. The circulation is therefore a rather sluggish process since the time between the first and the third waves is seven seconds and the entire length of the worm is only twenty-five millimeters.

As soon as approximately one sixth of the cœlom at the anterior end has been filled with fluid, anterior to posterior peristalsis begins at this end and continues in the manner just described for the posterior end; a primary wave of fluid leaves, followed by a second and a third and sometimes a fourth, the first wave being the largest and each succeeding one smaller. There is this difference, however, between the processes at the two ends; when a peristaltic wave arises at the anterior end of the uterus it pushes cœlomic fluid both anteriorly and posteriorly instead of sending it all posteriorly. This movement in opposite

directions occurs because the uterus does not completely fill the anterior end of the cœlom and consequently when it constricts it allows some fluid to move anteriorly. As a result, there is always a certain amount of fluid left at this end even after the last antero-posterior peristaltic wave has passed on. Another point of difference in the processes at the two ends is the fact that at the posterior end there is an instant's pause after the arrival of the fluid before it is sent back, while at the anterior end there is no pause, the peristalsis being immediately reversed. In view of this pause the posterior end can be considered as marking the beginning and the ending of the circulatory cycle. Seven cycles of the primary wave occur in two minutes. This rate was maintained by each of two worms in which the process was timed.

Frequently all of the secondary waves moving in a given direction have not reached the end toward which they are travelling before a primary wave starts toward them from that end. When this occurs the secondary wave keeps on moving until it meets the primary wave which then absorbs it and continues onward. When, as in the case of the posterior end, there is a momentary pause in the peristalsis of the uterus, the fluid does not necessarily come to rest throughout the entire cœlom, but secondary waves which may be moving keep on their course until they have reached the posterior end or until the primary wave from that end has met them.

Just why these secondary waves continue to move in this manner my observations did not make quite clear. The condition might be brought about by peristalsis from one end continuing until it met and was overcome by that originating at the opposite end. I am not prepared to say that this is the case, especially since, postero-anterior peristalsis begins at the anterior end almost synchronously with that at the posterior end. Possibly the impetus received from the peristalsis is sufficient to keep the secondary waves moving for a time even after peristaltic action has ceased.

As a wave moves along, a certain amount of the fluid composing it trails behind and comes to rest. This slipping back occurs because the uterus does not completely fill the cœlom.

The size of a given wave is maintained by carrying along the fluid in its path. As a result of the trailing fluid there is always some of it all along the cœlom. This residuum explains the arrival of small quantities of fluid at a given end with the peristalsis which precedes the arrival of the primary wave. The free play between uterus and body wall explains also why all of the fluid is not carried away from an end with the first peristaltic wave but is instead taken off in lessening quantities by several waves.

What relation the movement of the cœlomic fluid has to the well-being of the adult worm or its young depends upon the general function and composition of the fluid. Very little definite information has been published regarding this matter for the nematodes in general, and nothing, so far as I am aware, on the fluid of the genus *Camallanus*. It has been suggested that one of the functions served, in some cases at least, is to act as a medium for oxygen. If this be true the circulation in the present instance can be looked upon as of value in effecting a thorough distribution of the available oxygen.

There is some reason for believing that the circulation is of particular benefit to the young. Pointing to this conclusion is the fact that the peristaltic waves very effectively stir up the young and constantly bring different individuals into contact with the walls of the uterus and therefore nearer the cœlomic fluid.

From present knowledge it is rather hard to conceive what other purposes than those suggested would be served by such rhythmic constrictions of the uterus. Especially is it hard to see why there is a continual stirring up of the embryos bringing successively different individuals into contact with the walls of the uterus as is done in this case if it were not for some purpose connected with the surrounding medium. There is, however, a rather extensively held opinion that the cuticle of nematodes is impervious to all but the strongest fluids and even in some cases to strong formalin. If this were true the cuticle could possibly prevent absorption of oxygen. The view just mentioned is based on such examples as the vinegar eel, and on some instances in which adults of other species or their contained embryos have resisted preserving or fixing reagents for a considerable length

of time. It is doubtful whether careful or extensive work would prove this imperviousness to be as general or as great as it is sometimes thought to be.

The fact that the cœlomic fluid is red points suggestively to an oxydizing function. In other nematodes having red cœlomic fluid the color is said to be due to the presence of hæmoglobin and this is therefore probably the condition in these worms. Since their host is an aquatic animal and since they live rather near the anus, it would be a comparatively easy matter for a certain amount of oxygenated water to come in contact with them. This being true, hæmoglobin in the cœlomic fluid could take up any available oxygen.

In dissolving any doubt regarding the function of circulation in these worms it would be materially helpful to learn how extensive the process may be among nematodes in general and under what conditions it occurs. There is so little color differentiation in the fluid of most nematodes that possibly circulation may have been overlooked in species where it does actually take place. In the present case the redness of the fluid in contrast with the light background of the tissues made movements of the fluid noticeable and easy to follow. If the process is primarily an oxygenating one it might be found more frequently among species internally parasitic or otherwise living where thorough distribution of a small supply of oxygen would be a matter of importance.

LAKE LABORATORY,
OHIO STATE UNIVERSITY.